

Evaluation of Troposphere-Stratosphere Coupling in CFSv2

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Outline

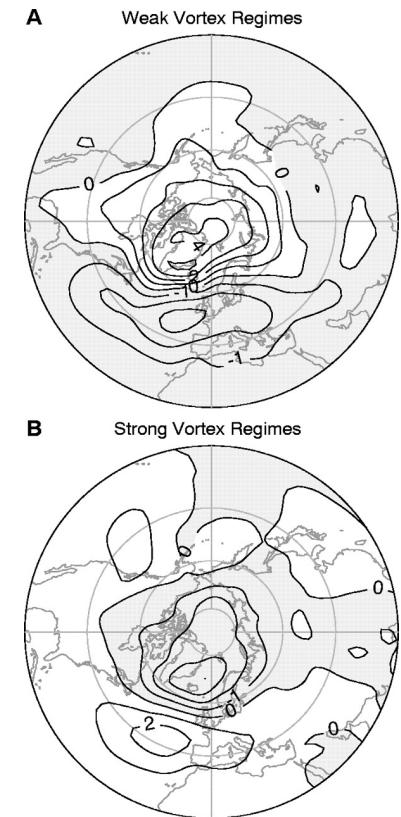
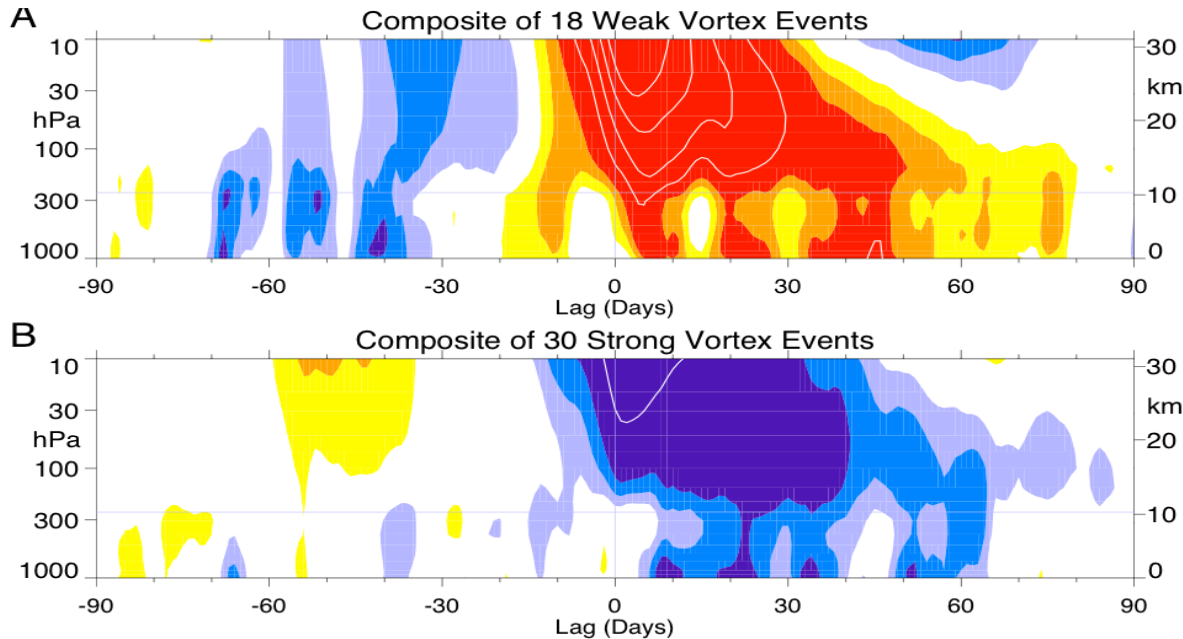
- Background
- Data sources
- Lower stratosphere polar vortex in CFSv1 and v2
- Stratosphere-troposphere coupling
- Summary and conclusions
- Way forward

NAS Assessment of intraseasonal to interannual (ISI) climate prediction and predictability

- ***Operational ISI prediction models should be improved to represent stratosphere- troposphere interactions.***
 - *Relatively long-lived (up to two months) atmospheric anomalies can arise from stratospheric disturbances.*
 - In sensitive areas such as Europe in winter, experiments suggest that the influence of stratospheric variability on land surface temperatures can exceed the local effect of sea surface temperature.
 - Additionally, while our weather and climate models do not often resolve or represent the stratospheric Quasi-Biennial Oscillation very well, it is one of the more predictable features in the atmosphere, and it has been found to exhibit a signature in ISI surface climate.

Downward progression of Northern Hemisphere Annular Mode (NAM)

(Baldwin and Dunkerton, 2001)



- Extreme events in the stratosphere are followed by anomalous pattern at the surface that resemble the NAM
- Extreme stratospheric events may provide forecast potential for weak 3 to 4

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Role of the Stratosphere in the Climate System

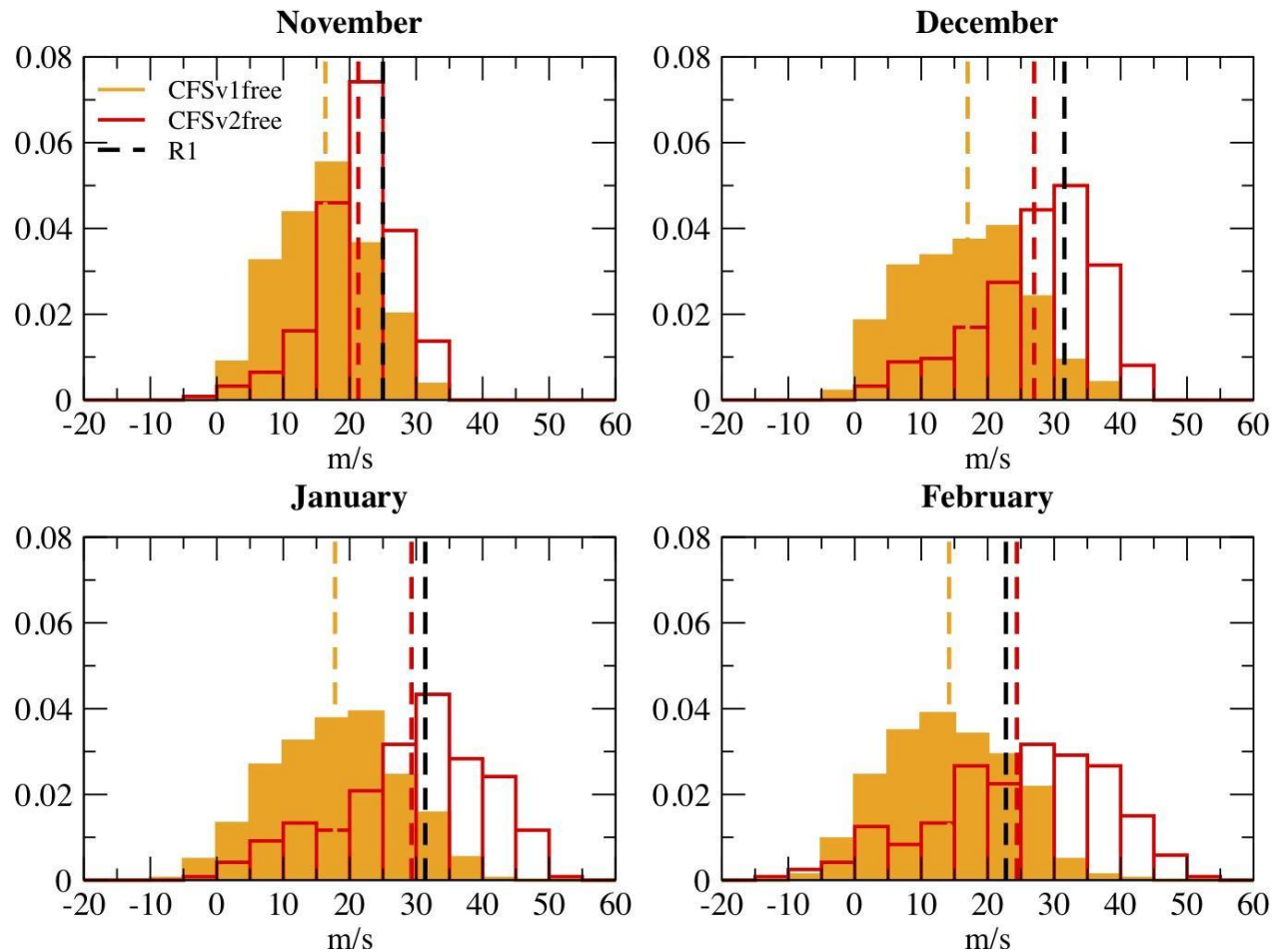
- Troposphere and stratosphere are closely coupled with impact of the troposphere on the stratosphere dominating.
- Stratosphere provides an important pathway by which tropospheric circulation anomalies can be modified.
- Impact of stratosphere on the troposphere via changes in the stratospheric basic state (due to ozone depletion, volcanic aerosols)
- Degrading the representation of stratospheric processes in GCMs has important implication for modeling the tropospheric climate state, its variability and its sensitivity to external forcing.

Model Data

- CFSRR (monthly mean output)
- Decadal runs with CFS (monthly mean output)
 - Thanks to Ed Schneider (COLA & GMU) for sharing CFSv2 coupled model output.
- AMIP runs with atmospheric component of CFS (daily output)

Comparison between CFSv1 and v2

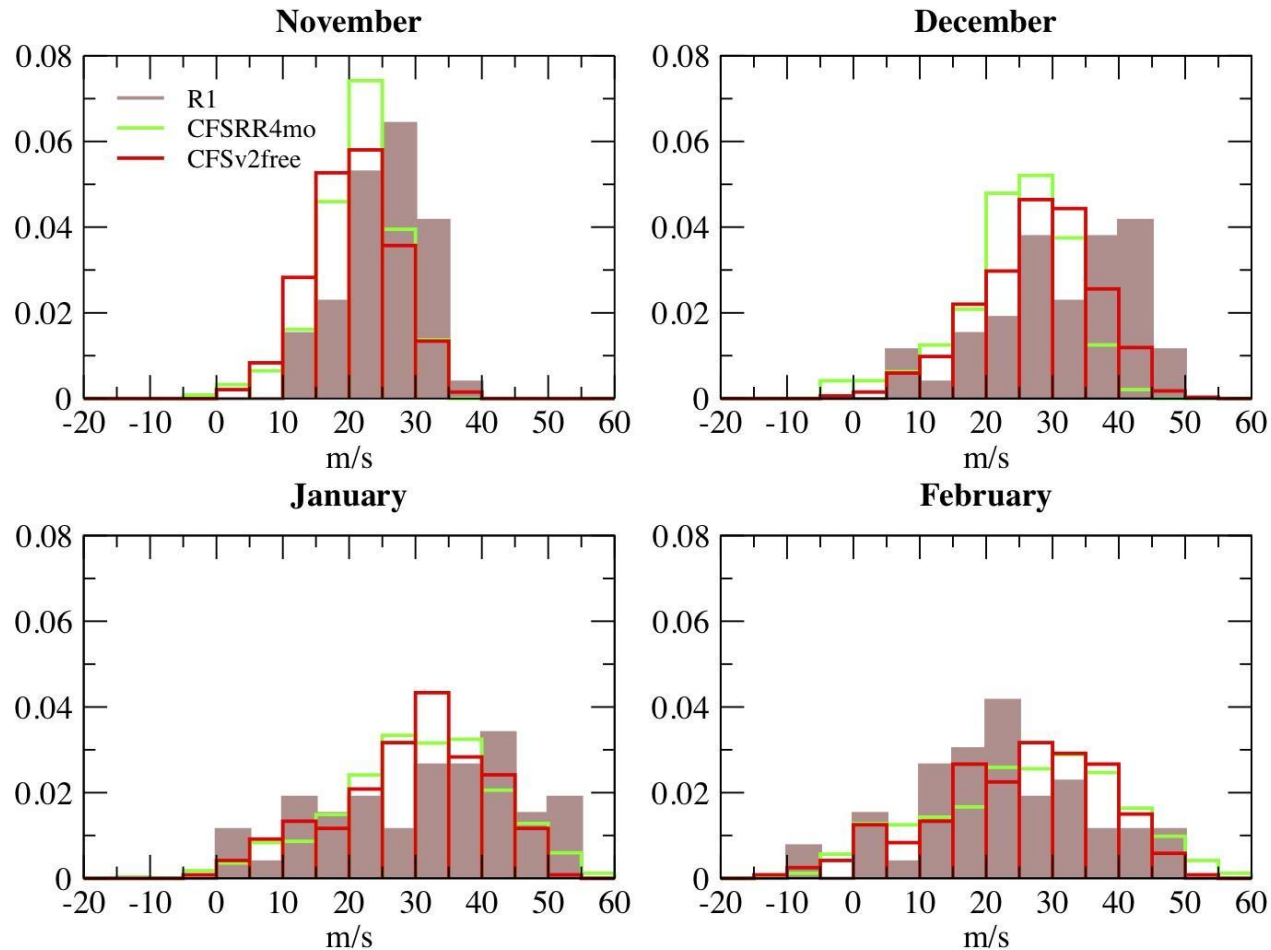
Zonal Mean Zonal Wind 60°N, 10hPa



CFSv1 and CFSv2 have very different polar night jet climatologies.

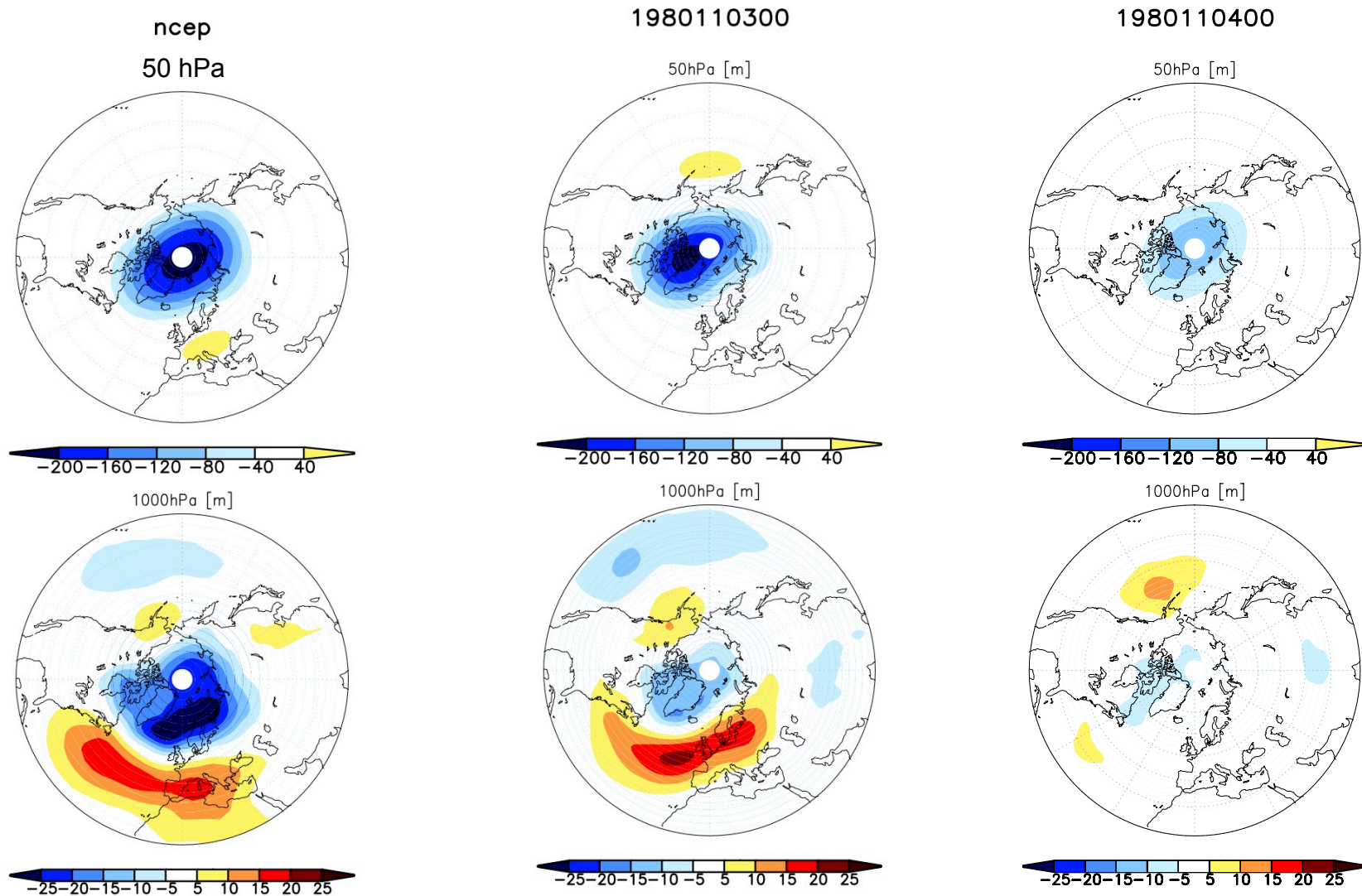
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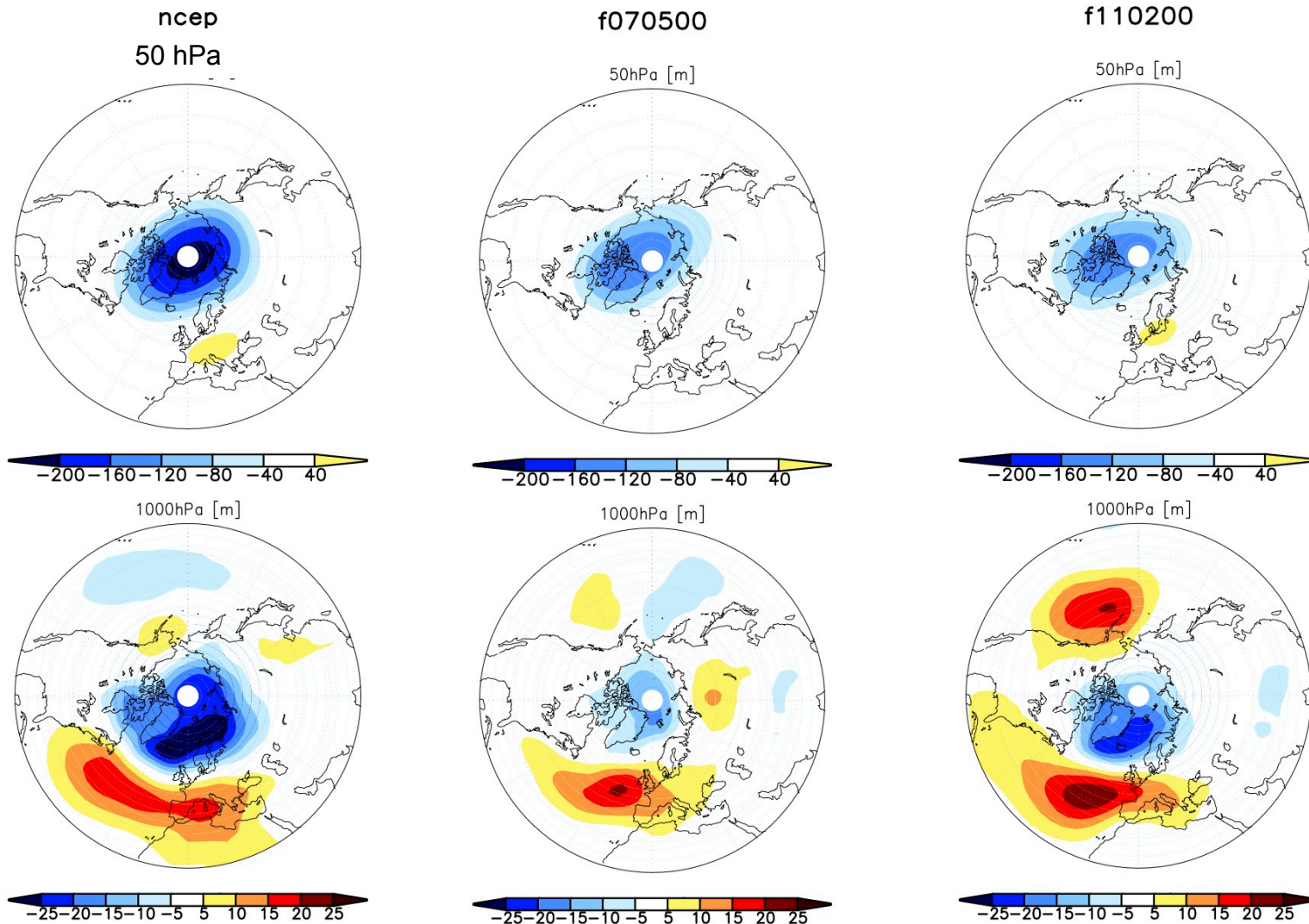


Variability range during D, J, F is similar between CFSv2 and reanalysis

Leading Coupled Mode of Variability of 50 and 1000hPa Height Fields (JFM mean)

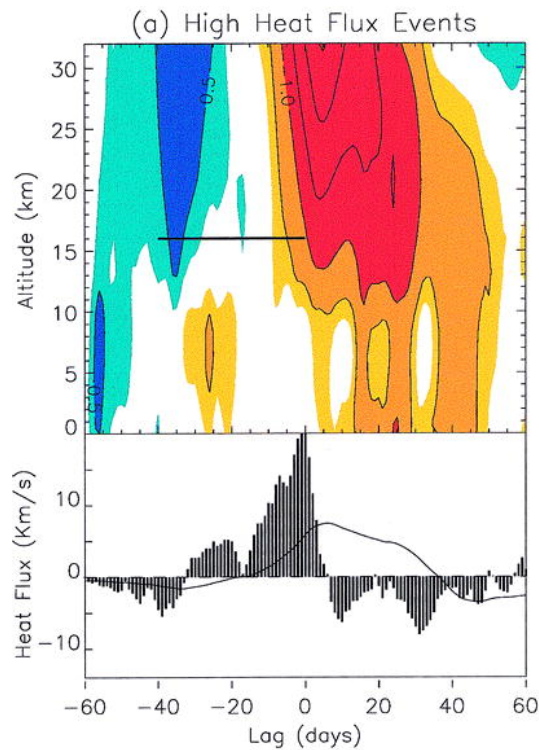


Leading Coupled Mode of Variability of 50 and 1000hPa Height Fields (JFM mean)



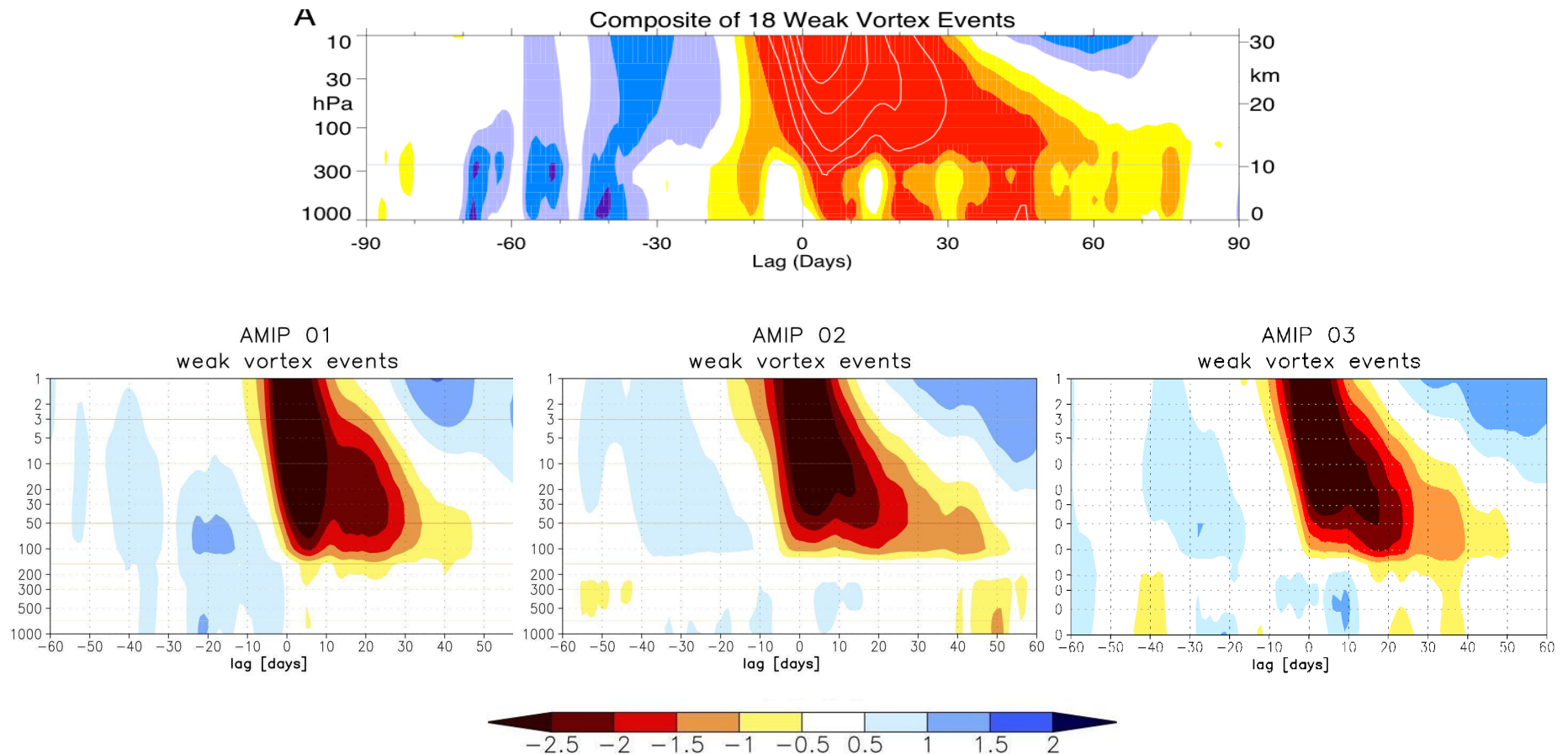
Downward Zonal Mean Coupling

- Dissipation of wave activity in the stratosphere
- Westward acceleration of the stratospheric flow
- Downward progression of westward zonal mean anomalies
- Lack of wave activity relates to downward progression of eastward zonal wind anomalies



Downward progression of NAM anomalies is determined by upward flux of wave activity (Polvani and Waugh, 2004)

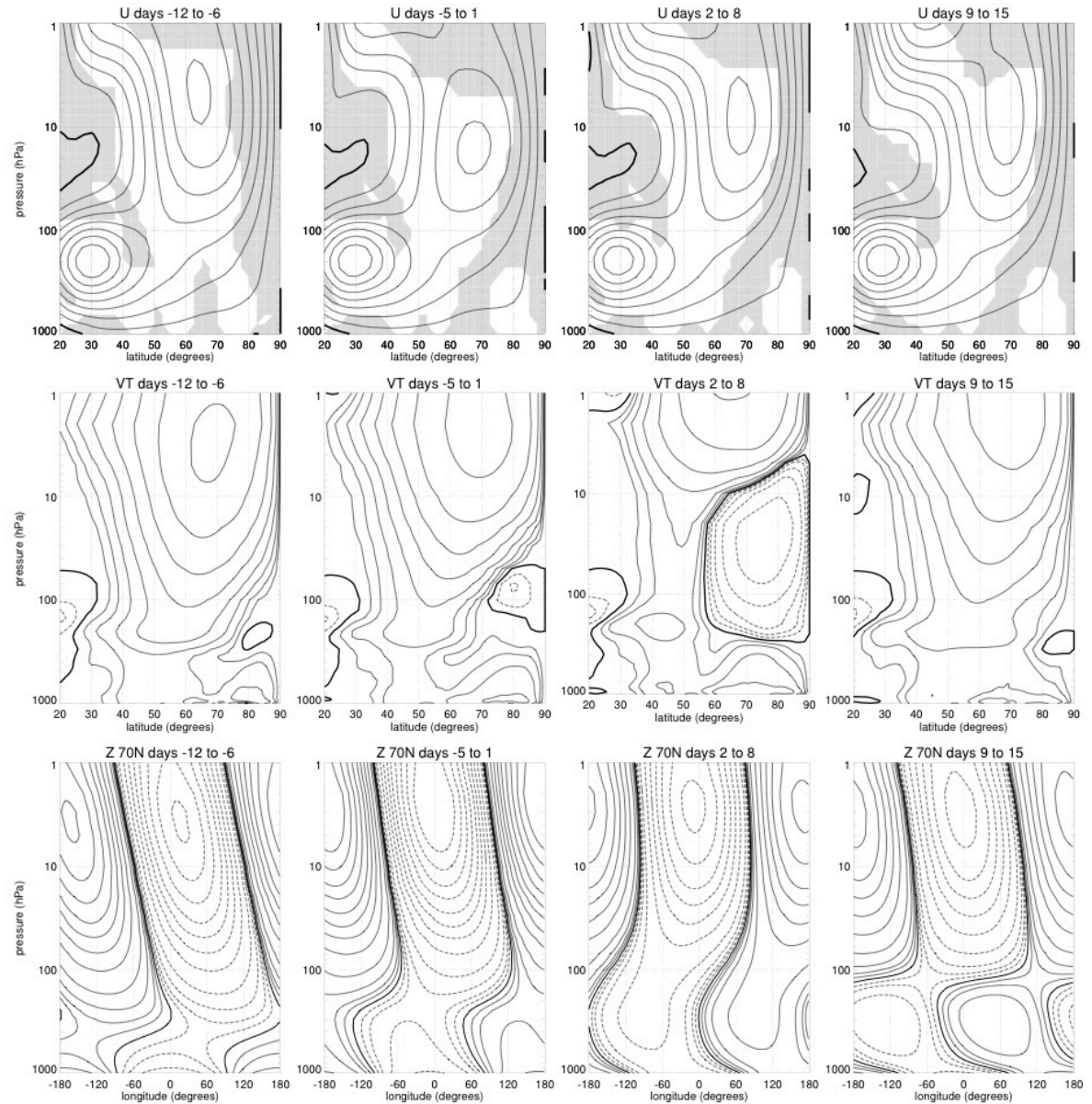
Downward Progression of Weak Polar Vortex anomalies (Zonal Mean Component of Annular Mode)



In AMIP simulations, SSW signature does not propagate into the troposphere. Such analysis should be repeated based on daily CFSRR output and different forecast leads as well as in free running coupled model.

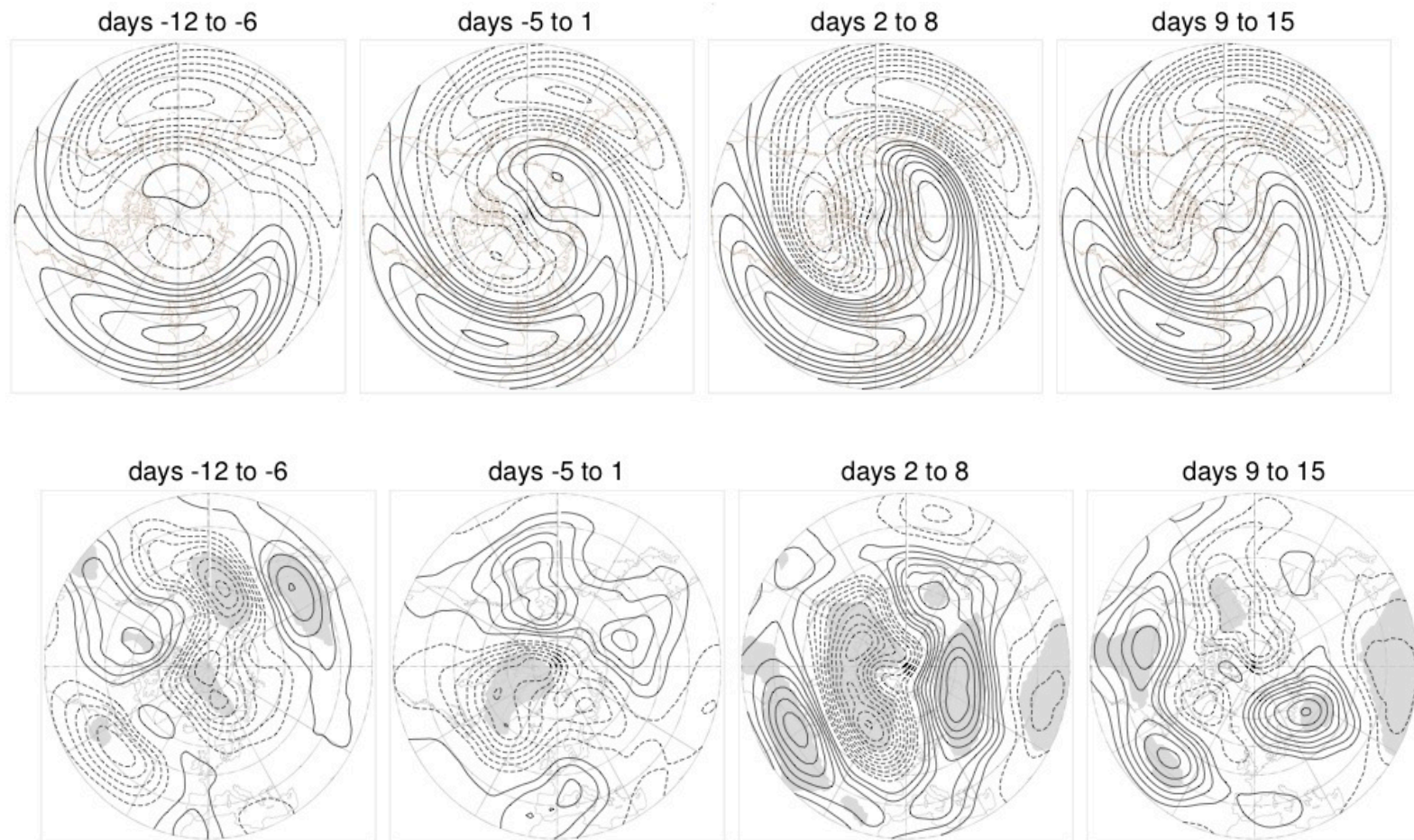
Downward Wave Coupling

- Wave activity that propagates into the stratosphere can approach a vertical reflective surface
- Wave activity then gets reflected back into the troposphere where it modifies the tropospheric flow



Shaw and Perlwitz, 2012

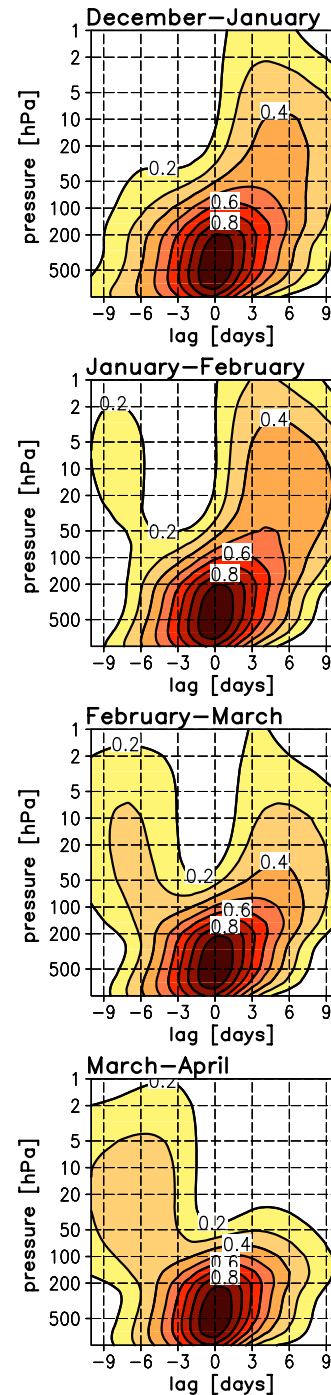
500 hPa Wave 1 and total 500 hPa anomalies during lifecycle of Wave reflection events



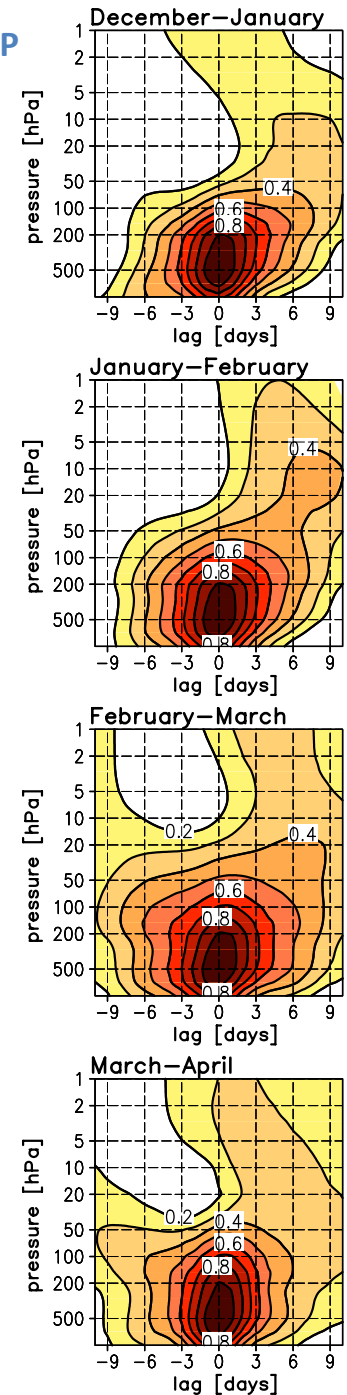
Wave One Propagation in Northern Hemisphere

- In model, upward propagation of wave activity is more disperse, especially in Feb-Mar
- Model does not capture downward wave coupling, most likely due to lack of formation of reflective configuration of stratospheric basic state
- In Mar-April, model shows very different propagation characteristics for planetary wave 1 than reanalysis

ERA40



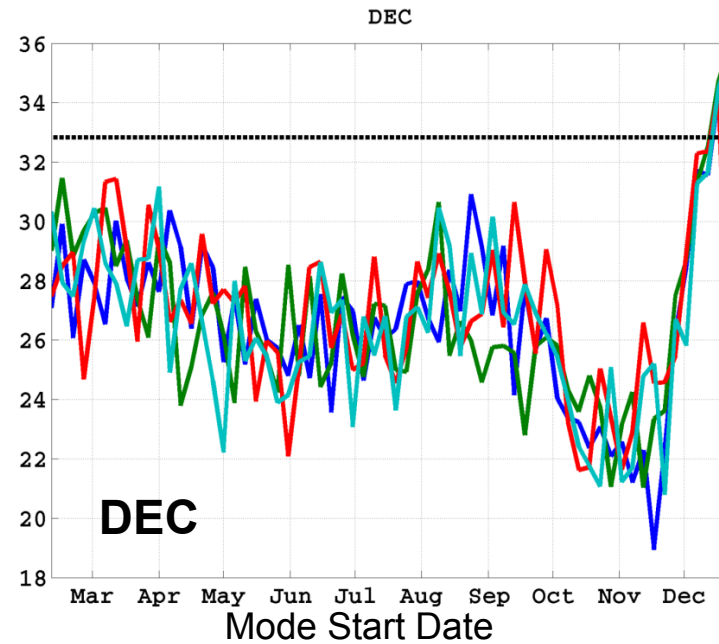
AMIP



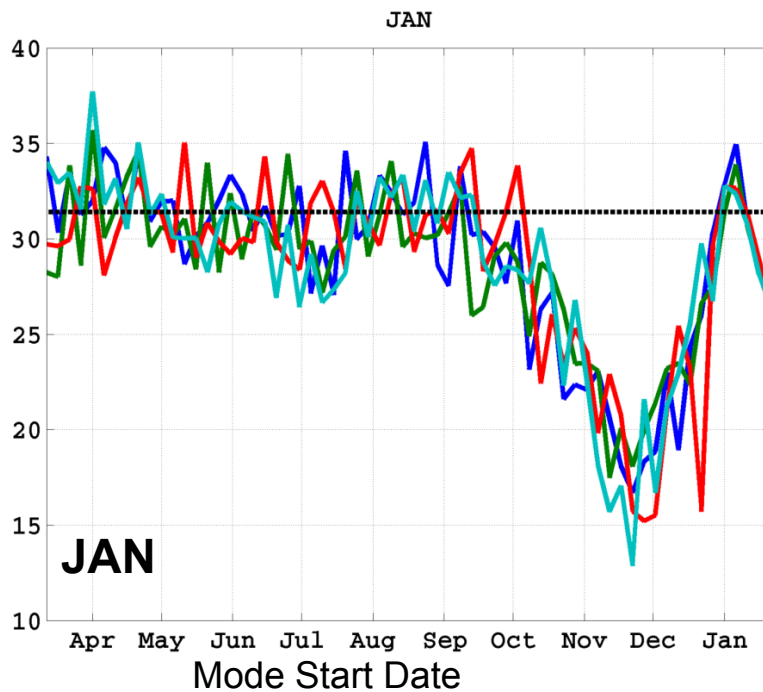
Spin Up Effect in CFSRR

**10hPa 60N
Zonal Wind at
different model
start dates
(Courtesy of
Emily Riddle)**

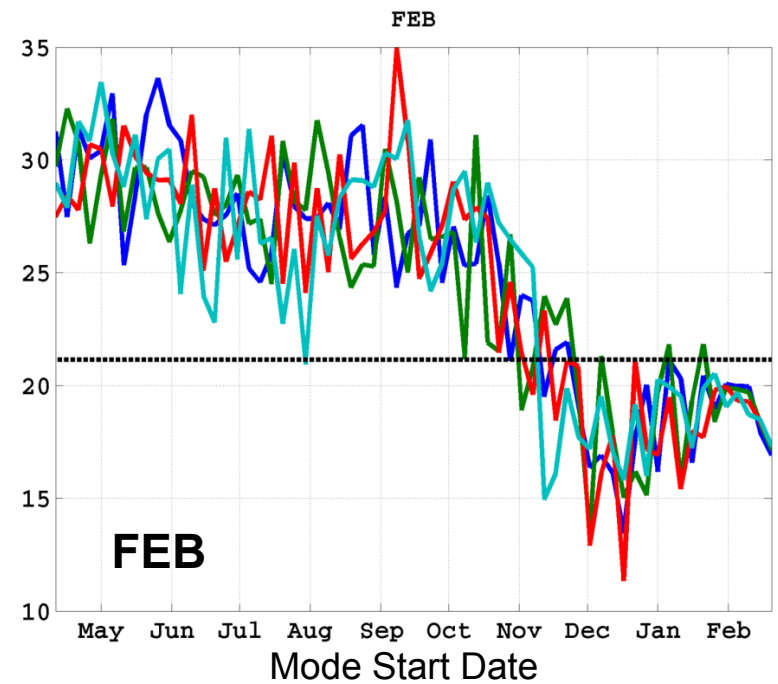
Vortex speed



Vortex speed

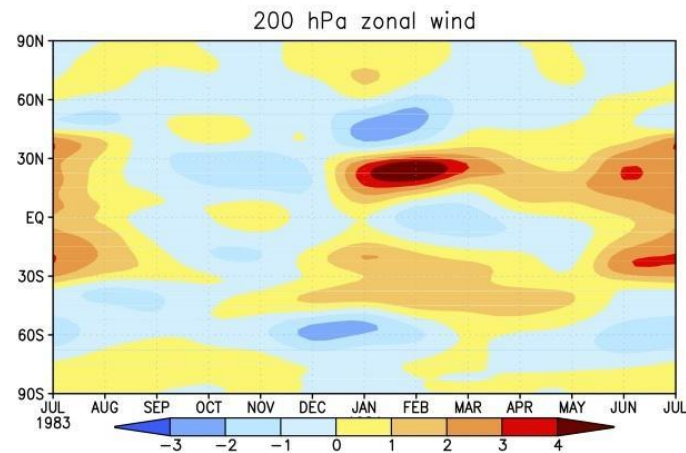
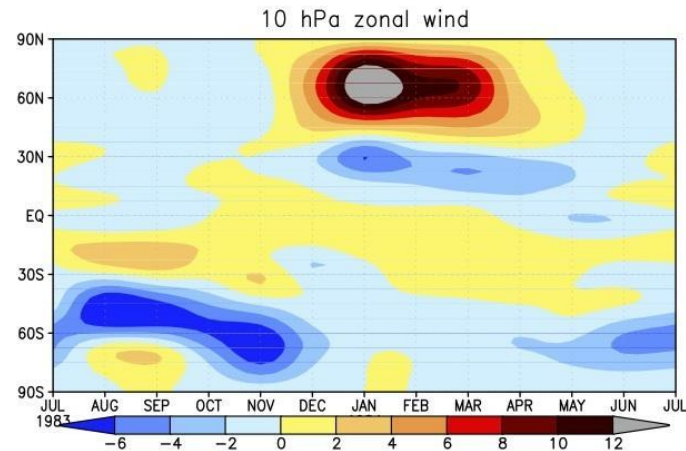
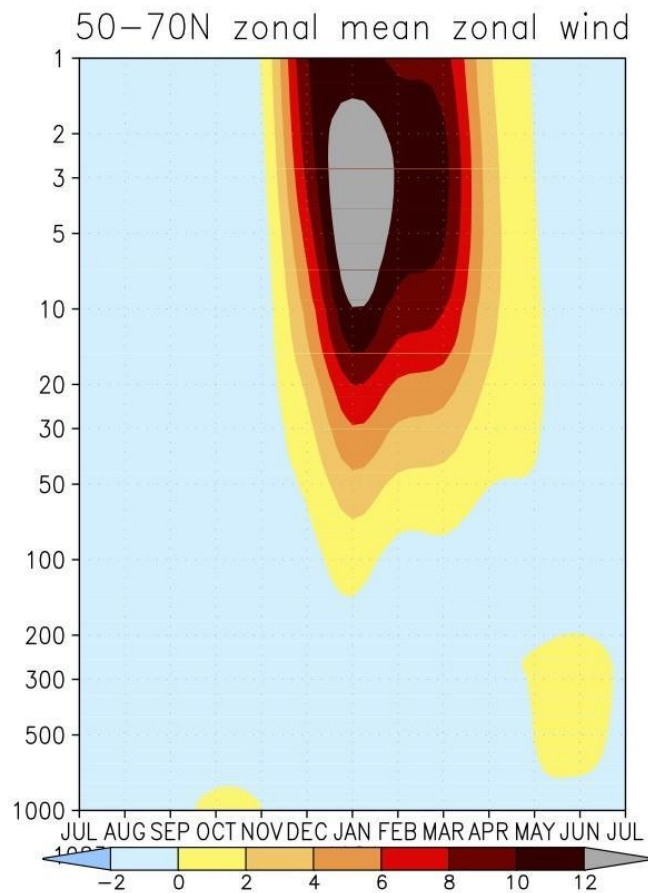


Vortex speed



Spin up effect

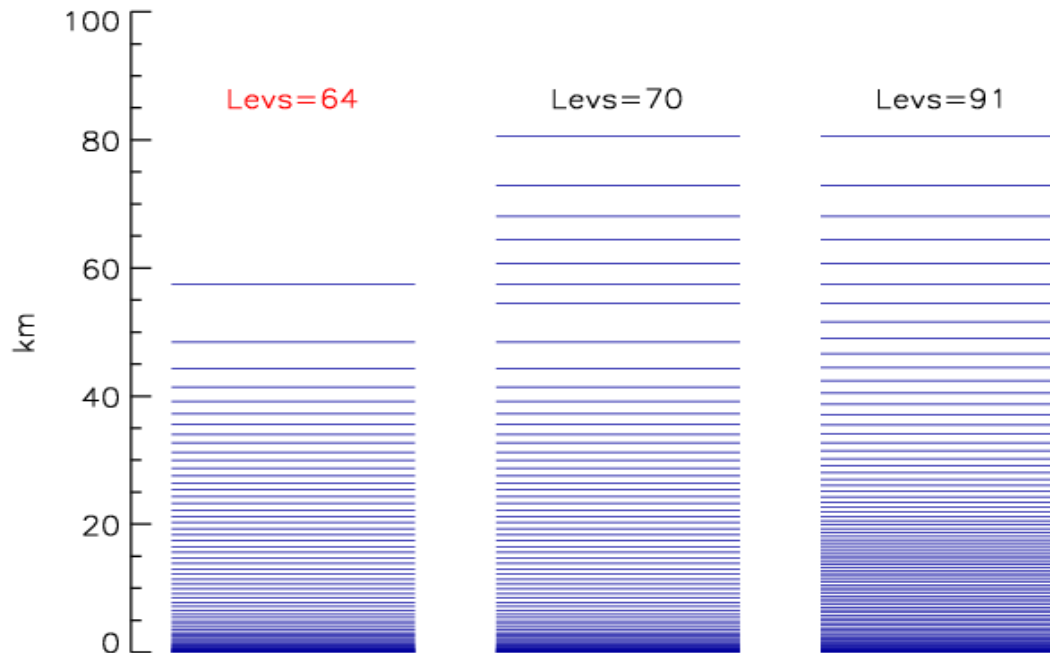
4mo minus 2mo lead times



Summary and Conclusions

- Climatology of stratospheric polar night jet is significantly different between CFSv1 and CFSv2.
- In CFSv2 polar vortex is too weak in early winter and too strong in late winter.
- Variability of stratospheric polar vortex is similar between CFSv2 and Reanalysis.
- Dynamic coupling between the stratosphere and troposphere is not well represented in the CFSv2.
- CFSv2 has a serious spin up problem that is mostly pronounced in the stratosphere but can also be seen in the troposphere - will degrade any assimilated stratospheric information with potential benefit for improved tropospheric forecast.

Way forward



- Analysis of CFSRR daily output of 45 day runs
- Raise model lid and increase number of vertical layers
- Include stratospheric gravity wave drag parameterization

Vision

- Improve stratospheric representation so that the CFS can generate QBO